



A NAVISTAR COMPANY

# **International<sup>®</sup> Medium Duty Full Power Hydraulic Brakes**

**Study Guide  
TMT-040701**

**INTERNATIONAL<sup>®</sup>**

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# **Program I: Introduction, Theory & System Operations**

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# Program I: Introduction, Theory & System Operations

## Section 1: Introduction

International® 4000 Series 4 x 2 trucks (including the RXT), and 4200 4 x 4 equipped with hydraulic brakes, built after August 21, 2006 feature the Meritor WABCO Full Power Brake system. The Full Power Brake system provides better pedal feel, shorter stopping distances, antilock brakes, and traction control.

But the Full Power Brake system offers a lot more, like Electronic Brakeforce Distribution to compensate for axle loading imbalances. And it does all this with simplified, computer assisted maintenance.

This system is unique because it doesn't use fluid pressure from the power steering pump, instead, electric pump motors pressurize nitrogen accumulators. In fact, the system works much like an air brake system except that accumulators replace the air tanks and a pump motor replaces the air compressor.

### Objectives

Participants will be able to:

- Identify the purpose and scope of this training series.
- Identify the unique design of the Full Power Brake system.
- Understand basic hydraulic and system principles.
- List and describe system features.

***“The following DVD program series covers complete International® Medium Duty Full Power Hydraulic Brake fundamentals.”***

Along with this advanced brake technology and performance, comes a greater challenge with respect to servicing the system.

The following DVD program series covers complete International® Medium Duty Full Power Hydraulic Brake fundamentals. It is designed to provide all the technical knowledge and skill necessary to diagnose and repair this highly advanced brake system.

This series is divided into six programs. The first program covers brake system theory. Then we cover features and components in detail. Then brake system modes of operation are covered, with a focus on antilock braking. The next program covers basic diagnostics and WABCO® TOOLBOX™ Software. Then, common service procedures are covered. Finally, repair procedures are demonstrated.

Once you have successfully completed this DVD, you will have all the information you need to properly service the International® Full Power Braking system.



## Section 2: Theory & System Operations

Hydraulic theory is based on the principle that a liquid will not compress. If pressure is applied to a liquid in a closed system, the pressure is transmitted equally throughout the system.

***“Hydraulic theory is based on the principle that a liquid will not compress.”***

Hydraulic brake systems operate with this theory. For example, if 20 psi is applied through the master cylinder, 20 psi can be measured anywhere in the lines.

In a similar manner, hydraulic principles dictate that the total amount of travel input into the system will also be transmitted equally throughout the system.

In other words, if the master cylinder piston is moved a distance of 1 inch, all affected brake caliper pistons will move a total of 1 inch throughout the entire system—assuming all pistons are the same size as the master cylinder piston.

However, force is typically increased at the wheel by increasing the size of the brake piston.

So, doubling the size of the brake piston in comparison with the master

cylinder doubles the force at the brake piston.

The trade off for twice the force in this example is that now, brake piston travel is cut in half while the master cylinder's travel remains unchanged.

In the same way, if the brake piston size is four times larger than the master cylinder piston, this translates to four times the pressure but only 1/4 the travel across the brake system pistons.

The Full Power Brake system utilizes Bosch® pin slide foundation brakes. Although the foundation technology remains much the same, many other aspects of the Full Power Brake system are enhanced with new design features and technology.

## Dual Circuit Design

***“The brake system is divided into two completely separate systems to protect against overall system failure.”***

Another key principle of the Full Power Brake system is dual system design. The brake system is divided into two completely separate systems to protect against overall system failure.

One master-cylinder piston and reservoir chamber is used to actuate the brakes on one axle and a second piston and reservoir chamber actuates the brakes on the other axle.

The primary system refers to the front brakes while the secondary system refers to the rear brakes.

Again, primary and secondary brake systems remain separate throughout—from the master cylinder, to the rotors.

Another basic feature of the Full Power Brake system is the Antilock Braking System, or ABS. Using microprocessor technology, the truck senses when the wheels are about to lock up during braking.

Using sensors positioned at each wheel end, the brake system electronic control unit, or ECU, determines which wheel has started to slow by comparing its rotational speed with the remaining wheels.

To avoid an imminent lockup condition, the ECU signals solenoid valves to reduce hydraulic pressure at the wheel until the wheel can momentarily recover.

Next, the ECU signals the solenoid valves to increase hydraulic pressure at this wheel so that momentary full braking can be achieved. This entire process is repeated several times a second until there is no longer a need to modulate braking.

***“The primary system refers to the front brakes while the secondary system refers to the rear brakes.”***

The synchronization of this process creates a pumping or pulsing action that ultimately allows the driver to realize the optimum balance between minimum stopping distance and vehicle stability, when forced into a hard and abrupt brake maneuver or when stopping on wet or slippery surfaces.

Generally, if ABS develops a malfunction, the brake system automatically reverts to non-ABS control and remains in this state until the fault has been corrected.

The driver is alerted that the antilock system is not functioning by the dash-mounted warning light. When in this state, wheel lockup can occur if the driver over-brakes.

Automatic Traction Control, or ATC, is another Full Power Brake related feature. ATC is an option on the International<sup>®</sup> 4000 Series 4 x 2 vehicles.

***“ATC prevents wheel slippage or traction loss during vehicle acceleration.”***

While ABS prevents a wheel lock-up or skidding condition during deceleration of the vehicle, ATC prevents wheel slippage or traction loss during vehicle acceleration.

It accomplishes this with the Full Power Brake ECU, by monitoring wheel speed to determine if one of the rear wheels

is starting to spin when compared to the non-drive wheels. When this condition is evident, the ECU signals the ATC solenoid valves to apply hydraulic pressure to the brake caliper of the spinning wheel. This is known as differential braking.

By only applying the brakes at the spinning wheel, power is transferred from the slipping wheel to the opposite non-slipping wheel. The non-slipping wheel allows the vehicle to gain momentum and move with more traction.

At the same time, the ATC system flashes a dash indicator lamp to alert the driver that a wheel spin condition is occurring.

When both wheels on a powered axle start spinning at speeds below 31 mph, the ATC system works with the engine control module, or ECM, to reduce engine torque so that the slipping wheels can recover. Under these conditions, differential braking may also occur.

At speeds above 31 mph, all ATC events are controlled with engine torque only—no differential braking is applied above 31 mph. ATC is available with International® I-6 and VT 365 engines.

***“Under these conditions, differential braking may also occur.”***

The next feature of the Full Power Brake system is Electronic Brakeforce Distribution, or EBD.

Using the ECU's microprocessing capabilities and solenoid valves already discussed with ABS, the system identifies front-to-rear wheel slip imbalances during braking due to axle loading. Then the ECU distributes braking forces in proportion to axle loading to render a balanced brake application on the vehicle.

***“Memory within the ECU circuitry maintains a record of brake system operations.”***

Next is operational memory. Memory within the ECU circuitry maintains a record of brake system operations, such as the number of brake applications and the number of “hard-to-extreme” braking occurrences.

These records may be used to schedule preventive maintenance more effectively and efficiently.

Finally, a manual parking brake system comes standard on trucks equipped with the Full Power Brake system. An option is the Spring Applied/Air Release, or SAAR, powered parking brake system.

The SAAR canister uses air pressure to release the parking brake, while a mechanical spring applies the parking brake. A dash warning light alerts the

driver to problems with the powered parking brake system. The Spring Applied/Air Release powered parking brake system is not part of the Full Power Brake system.

With these principles and features in mind, including the laws of hydraulics, pin slide brake technology, dual system design, ABS, ATC, and EBD, let's take a look at each component in the overall Full Power Brake system.

## Conclusion

This concludes Program I of the Medium Duty Full Power Brakes series. Completion of this educational process is a key component toward International<sup>®</sup> technician certification. You are now required to take a post-test via ISIS<sup>®</sup>/Education/Service/Online Testing.

***“With these principles and features in mind ... let's take a look at each component in the overall Full Power Brake system.”***







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# **Program II: Full Power Brake Component Features**

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# **Program II: Full Power Brake Component Features**

## **Section 1: Brake Pedal**

The driver applies mechanical force to the brake pedal, which is transmitted through the push rod to the master cylinder.

## **Section 2: Master Cylinder Assembly**

The master cylinder/brake fluid reservoir unit is mounted to the engine side of the cowl panel in front of the driver.

It consists of a dual channel piston assembly, providing separate circuits for the front and rear brakes. It also contains the spring pack that returns the brake pedal to the up position.

The reservoir includes internal baffles to provide a protected volume of brake fluid for the master cylinder in the event of a leak at the reservoir or anywhere else in the system.

An external sensor mounted to the bottom of the reservoir detects when the brake fluid level is low. It instantly

### **Objectives**

**Participants will be able to:**

- **List and describe the purpose of each component in the system and how they work together.**

***“Both the fluid level sensor and the travel switch are replaceable without draining any brake fluid.”***

alerts the driver via a warning light located in the instrument cluster.

The travel switch that detects brake actuation is also mounted to the master cylinder. Both the fluid level sensor and the travel switch are replaceable without draining any brake fluid.

The purpose of the master cylinder is to translate the pedal force applied by the driver into the hydraulic pilot signals that are routed to the relay valve at the underside of the hydraulic compact unit, or HCU. Unlike earlier systems, the pressure from the master cylinder only acts as a pilot pressure signal to the HCU and is not directly plumbed to the calipers.

### **Section 3: Hydraulic Compact Unit (HCU)**

The Hydraulic Compact Unit acts as the heart of the system. The HCU is located on the inside left frame rail, behind the driver's position.

Like the master cylinder, the HCU is divided into front and rear hydraulic fluid routing passages to control the primary and secondary brake circuits. The components located to the front of the HCU service the rear axle while the components to the rear service the front axle.

However, the tubes feeding the front axle calipers are connected at the front while the rear axle calipers are fed by the tubes connected at the rear of the HCU.

For safety, two pressure relief valves are included to protect against overpressure.

Although there are two circuits, the electronically controlled ABS valves of the HCU allow independent control of braking force at each of the four wheels.

***“Two pressure relief valves ... protect against overpressure.”***

## **Section 4: Relay Valve**

First, a dual circuit relay valve assembly is located at the bottom of the HCU. This valve receives signals from the primary and secondary hydraulic lines coming from the master cylinder.

Then, proportionately, it routes brake fluid from pressurized accumulator circuits to the wheel ends. The relay valve is also actuated by the ATC valves during an ATC event on vehicles with Automatic Traction Control.

## **Section 5: HCU Reservoir**

The HCU also includes its own brake fluid reservoir. It is connected to the master cylinder reservoir through a low-

***“This reservoir assures that the motorized pumps and accumulators have a ready supply of brake fluid.”***

pressure gravity feed hose, allowing both reservoirs to be filled from the master cylinder location.

This reservoir assures that the motorized pumps and accumulators have a ready supply of brake fluid.

Like the master cylinder reservoir, it is divided into two channels with a baffle. The front half of the reservoir supplies the rear axle through one port, while the rear half of the HCU reservoir supplies the front axle through another port.

## **Section 6: Accumulators**

Both the front and rear brake circuits have their own accumulator. These accumulators are energy storage devices, with a lifetime charge of a nitrogen gas mixture on one side of a rubber membrane and brake fluid on the other side. Each accumulator has a factory-installed gas charge of 1087 psi.

The brake fluid under pressure in the accumulators is the force used to stop the vehicle, much in the same manner that compressed air in the air tanks is the force used in air brake systems.

In addition, when the accumulators are fully charged with brake fluid, the vehicle can complete 15–20 full apply

reserve stops should the electric pump motors fail to operate.

## Section 7: Electric Motors

The system also includes two independent electric pump motors, one each for the front and rear hydraulic circuits, plus each motor is wired to separate electrical circuits. Each pump motor is fused by a battery-powered, 30 amp maxi-fuse located on the outside of the cowl panel.

These motors drive pumps that charge the accumulators with brake fluid to maintain pressure at 1770–2320 psi during normal operation.


The motors are controlled by the ECU based on readings from two fluid pressure sensors inside the HCU.

## Section 8: Electronic Control Unit (ECU)

Next is the Electronic Control Unit, or ECU. It's the brain of the Full Power Brake system.

It contains the electronic hardware necessary to control the system. It provides all of the electronic control required for normal braking, ABS operation, ATC operation, and EBD. It also contains memory to store braking

***“The ECU is the brain of the Full Power Brake system.”***



***“The ECU interfaces with the other brake system components.”***

operational records and diagnostic trouble codes.

Also, the ECU interfaces with the other brake system components, as well as the vehicle electrical system through waterproof connectors. The 2-pin and 31-pin connectors are part of the ECU housing. The ECU also controls electric power to the two pump motors.

The ECU is fastened to the non-frame-rail-side of the HCU.

## **Section 9: Electronic System Controller (ESC)**

The ECU receives certain information from the vehicle Electronic System Controller, or ESC, which is mounted to the inside of the cowl, behind the instrument panel.

In addition, the ECU communicates with the gauge cluster, through the ESC, whenever a warning or status indicator light is turned on or off.

## **Section 10: ABS/ATC Solenoid Valves**

On non-ATC equipped vehicles, the ECU is mounted directly over eight solenoid valves to control the brakes in



an ABS event; one ABS inlet valve and one ABS outlet valve per wheel end.

On trucks equipped with ATC, there are two additional solenoid valves in the HCU. These valves are used for the ATC function and work with the ABS solenoid valves to control the brake fluid pressure at the spinning drive wheel during an ATC event.

In addition to the solenoid control valves, two pressure sensors monitor the pressures in the front and rear brake systems and will, when necessary, turn the pump motors on or off. One pressure sensor is dedicated to the primary braking system and the other to the secondary braking system.

***“One pressure sensor is dedicated to the primary braking system and the other to the secondary braking system.”***

## **Section 11: Brake Lines**

Steel brake lines and flexible high pressure rubber hoses connect the HCU to the calipers.

## **Section 12: Wheel End Assembly**

Calipers, brake pads, and rotors provide the friction forces needed to bring the vehicle to a stop.

Again, International® 4000 Series Trucks feature Bosch® pin slide foundation brakes. The ABS magnetic

***“Keep in mind that broken or missing tone wheel teeth or corrosion between the teeth can cause inaccurate wheel speed signals.”***

coil/pickup sensors provide wheel speed information to the ECU for ABS, EBD, and ATC events.

Keep in mind that broken or missing tone wheel teeth or corrosion between the teeth can cause inaccurate wheel speed signals.

Calipers, brake pads, rotors, and sensors are covered in detail in the International® Diamondlife™ disc brake training series.

The Spring Applied/Air Release, or SAAR, parking brake system uses air pressure from the air tank to release the brake drum assembly.

It is a combination of mechanical and air assemblies. The main components of the SAAR parking brake system are the parking brake air control valve, SAAR canister, brake cable, and the brake drum assembly.

### **Section 13: Parking Brake Air Control Valve**

The dash-mounted parking brake air control valve regulates the application and release of air at the SAAR canister.

This parking brake system is equipped with an air gauge and warning light separate from the Full Power Brake

system. If the air pressure within the air tank has been reduced to approximately 70 psi due to system leakage (483 kPA), the light will activate.

If air pressure is further reduced to approximately 30 psi (207 kPA), the parking brake control knob will automatically pop out and fully apply the parking brake.

Before this point is reached, partial parking brake application will occur, prior to automatic application of the control valve, for a controlled and less abrupt braking event.

## **Section 14: Parking Brake Cable**

The parking brake cable is a two-piece cable that connects the SAAR canister to the drum assembly. The SAAR canister is located at the inside left frame rail, just ahead of the rear-axle-mounted parking brake drum assembly. The cable adjustment point is at the rear of the SAAR canister.

If the event of low air pressure or a mechanical failure that causes the parking brake to remain in the applied position, the following steps are recommended if the vehicle requires towing.

***“If air pressure is further reduced ... the parking brake control knob will automatically pop out and fully apply the parking brake.”***

Apply shop air at the supply reservoir and bring the SAAR system up to full operating pressure and then disconnect from the shop air source.

Verify whether or not the SAAR canister will remain in the released position with no air system leakage. If the previous step proves unsuccessful, proceed by disconnecting the cable from the canister.

First dump any remaining air from the system by pulling the dash panel park brake knob. Do NOT bleed the supply reservoir.

Next, loosen the jam nut and unthread the adjustment rod from the SAAR canister to reduce tension on the cable. Continue to unthread the adjustment rod all the way and remove it from the canister.

## **Section 15: SAAR Canister**

***“The SAAR canister is the main component of the air-powered parking brake system.”***

The SAAR canister is the main component of the air-powered parking brake system. It includes a valve that controls the release or application of the parking brake.

When the dash-mounted parking brake valve is pressed, the SAAR canister becomes pressurized with air. This pressurized air causes the piston and

shaft to move rearward and compress the two internal springs behind the piston, relieving the cable tension and releasing the parking brake.

When the driver pulls the parking brake valve to apply the parking brake, the SAAR canister is depressurized as the air is dumped via a quick release valve. Finally, the two springs decompress and apply the parking brake.

Four instrument cluster warning lights provide feedback to the driver concerning the operation and condition of both the brake and the ATC systems based on continuous Full Power Brake ECU monitoring.

These four indicators identify conditions resulting from a fault within the system or when service is required. For example, the fluid level sensor. If a lit indicator is the result of a malfunction, diagnostic codes identifying the source will be stored in the ECU.

The warning lights that make up the system include brake pressure, master cylinder fluid level, ABS, and ATC.

Keep in mind that these lights are all tested during initial key on. They are programmed through the ESC and operate based on inputs from the ECU.

## NOTE

**Retrieval of diagnostic codes is covered in Program IV of this series.**

## Section 16: Brake Pressure Indicator

The red brake pressure warning light indicates a low pressure condition if one of the two brake circuits is failing. A continuous brake pressure warning light, referred to as a half system warning, is followed by a warning buzzer.

A flashing brake pressure warning light with warning buzzer is referred to as a full system warning. It means that both the primary and secondary circuits are experiencing this fault.

The full system warning is also combined with the Engine Control Monitor, which limits the vehicle speed to 25 mph maximum, once the vehicle drops below this speed threshold.

The driver should pull the vehicle to the side of the road as soon as safely possible.

## Section 17: Fluid Level Indicator

The fluid level sensor and switch assembly is located in the bottom of the master cylinder reservoir and signals the ECU when the brake fluid is

### **FULL POWER BRAKE FACT:**

**A fault is detected by the ECU when pressure falls below 1550 psi. The normal operating range is 1770–2300 psi for both the primary and secondary circuits.**

below the MIN mark at the front of the reservoir.

The ECU then commands the red Fluid Level Warning light to illuminate continuously until fluid is added to the appropriate level.

## **Section 18: ABS Indicator**

The amber ABS warning light indicates a fault when it is continuously lit. Some fault conditions include:

- The Full Power Brake system ECU is not receiving power.
- The wheel speed sensors are too far away from the tone ring, the sensors are non-approved, or the sensors are sending no signal at all.
- The ABS solenoid valves aren't functioning properly.
- The ECU has determined that the voltage and current draw across the solenoid valves are out of range.
- There is a loss of communication between the ECU and ESC.

***“The amber ABS warning light indicates a fault when it is continuously lit.”***

## Section 19: ATC Indicator

The Automatic Traction Control dash light illuminates in the “solid on” mode when there is a fault with the ATC circuits or when the truck is experiencing an ATC event.

When the ATC switch is set to the **DISABLE** or **MUD/SNOW** position, normal traction control is disabled and replaced with the mud and snow mode.

With the switch in this position, it is illuminated and the ATC dash light flashes. The mud and snow mode is also known as a reduced sensitivity mode, allowing for more wheel slippage before an ATC event.

### NOTE

**Fault code retrieval is covered in Program IV of this series.**

In terms of faults, the traction control warning light illuminates when the ECU detects a problem with:


- the two rear wheel speed sensors
- the two ATC solenoids
- the two ABS solenoids that serve the rear brakes
- the ATC lamp function
- the ATC switch
- the power circuits to the solenoids



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## Conclusion

This concludes Program II of the Medium Duty Full Power Brakes series. Completion of this educational process is a key component towards International<sup>®</sup> technician certification. You are now required to take a post-test via ISIS<sup>®</sup>/Education/Service/Online testing.







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# **Program III: Braking Modes**

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## Program III: Braking Modes

Before performing diagnostics, it's a good idea to understand the different brake system modes of operation: Normal braking, ABS braking, and Automatic Traction Control.

Also, the Electronic Brakeforce Distribution mode may occur. In general, the ECU monitors the wheel speed sensors and other system parameters to determine which operational mode is necessary.

It is important to note that the relay valve is hydraulically controlled while all other valves are electronically controlled solenoid valves. This portion of the series elaborates on each Normal, ABS, and ATC mode.

### Section 1: Normal—Brakes Not Applied

Let's discuss the normal modes. To review, the brake system is divided into two circuits: the primary circuit controls the front axle and the secondary circuit controls the rear axle.

The motor-driven pumps maintain pressure in the accumulators where it is stored to provide braking energy. The

### Objectives

Participants will be able to:

- **List and describe the system modes of operation and how they occur.**
- **Identify when engine torque is involved with the system.**

***“Without the brakes applied, all of the solenoid valves are in their non-energized state.”***

pressure is maintained between 1770 and 2320 psi.

Without the brakes applied, all of the solenoid valves are in their non-energized state. The only pressurized brake fluid is between the pump outlets and the relay valve pistons. The state of the relay valve pistons block the pressurized brake fluid from the rest of the system.

Since the ABS solenoid valves still remain in their normal positions, unpressurized brake fluid flows back from the brake calipers past the ABS valves and relay valve pistons until it dumps into two return ports of the HCU reservoir.

## **Section 2: Normal–Brakes Applied**

The second normal mode is when the brakes are applied. When the brake pedal is pressed, two “pilot signals” are sent from the master cylinder through the primary and secondary lines to the HCU relay valve.

As already mentioned, these two hydraulic lines are dead-headed at the HCU relay valve. The fluid in these lines applies pressure to the relay valve, but doesn’t flow into the HCU.

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In response to these pilot signals, the two pistons within the relay valve route pressurized brake fluid from the accumulators through the normally open ABS inlet valve at each wheel end and is contained by the normally closed ABS outlet valve.

The relay valve is designed to apply braking pressure to the wheel end calipers in proportion to the strength of the pilot signals generated by the master cylinder.

When the brake pedal is released, the relay valve moves to block the flow of pressurized brake fluid from the accumulators. Then the pressurized brake fluid in the calipers is allowed to return to the HCU reservoir through the open ABS inlet valve and a portion of the relay valve.

***“The relay valve is designed to apply braking pressure to the wheel end.”***

### **Section 3: ABS**

The ABS braking mode may begin during Normal braking mode when the ECU determines that a wheel is about to lock up.

During braking, in addition to monitoring the master cylinder travel switch, the ECU monitors the wheel speed sensors located at each of the four wheel ends.

An ABS event occurs when the brake pedal is pressed and the ECU determines, from the sensor signals, that a wheel is about to lock up.

During an ABS event, the ECU controls ABS operation by energizing and de-energizing the solenoid-controlled valves that route the brake fluid to the wheel end calipers.

The valve coils are contained in the ECU assembly, while the valve cores are part of the HCU assembly.

***“The wheels can enter the ABS mode independently.”***

The wheels can enter the ABS mode independently. If only one wheel is starting to lock up, it will operate in the ABS mode while the other three wheels continue to operate in the Normal braking mode.

While in the ABS mode, the ECU adjusts the brake force by electronically cycling through three ABS states several times per second. This prevents any wheel from locking, and at the same time, maximizes brake force by modulating brake pressure.

The three ABS states are: Decrease Pressure, Hold, and Increase Pressure.

Once in the ABS mode, the system remains in ABS mode until either the brake pedal is released, as indicated



by the master cylinder travel switch or when the wheel speed sensors no longer indicate a probable lockup.

In the first state of an ABS event, the ECU enters Decrease Pressure. In this state the ECU closes the ABS inlet valve and opens the ABS outlet valve for the affected wheel.

***“In the first state of an ABS event, the ECU enters Decrease Pressure.”***

This action decreases the brake fluid pressure applied to the wheel caliper, allowing the wheel to recover and continue rotating.

The closed ABS inlet valve isolates the caliper from the pressurized brake fluid in the accumulator. The open outlet valve allows the pressurized brake fluid in the caliper to return to the HCU reservoir.

Once the skidding wheel approaches recovery, the ECU initiates either the ABS Hold state or the ABS Increase Pressure state, or a combination depending on the dynamics of the ABS event.

In the ABS Hold State the ECU keeps the normally open ABS inlet valve closed for the affected wheel and allows the ABS outlet valve to return to its normally closed state.

The ABS Hold state is initiated during an ABS event when the ECU determines that the brake pressure is optimum in terms of delivering the ideal balance between braking force and available stopping traction.

With both the ABS inlet and outlet valves closed, brake fluid pressure remains constant during the length of the Hold state.

The ABS Increase Pressure state is initiated during an ABS event when the ECU determines that brake force is not optimized in comparison with available stopping traction.

With the inlet valve open and the outlet valve closed, the brake fluid pressure applied to the wheel caliper increases according to the pressure placed on the brake pedal.

Brake force is allowed to increase since lock up has been prevented and traction has been restored with either a previous Decrease Pressure state or a Hold state or both.

***“These states are cycled many times a second by the ECU.”***

Again, these states (Decrease Pressure, Hold, and Increase Pressure) are cycled many times a second by the ECU and continue until the vehicle has come to a complete stop or the brake pedal has returned to its up position. At

this point, the Full Power Brake system returns to its Normal braking mode.

## Section 4: ATC

Now let's move to ATC modes. The optional ATC system includes an ATC inlet valve and an ATC outlet valve. More specifically, the ATC inlet valve provides a second hydraulic input to the relay valve.

These two valves are situated in the HCU and work with the two rear ABS inlet valves and the two rear ABS outlet valves to restore traction.

When the system is in the ATC Inactive mode, the brake pedal is in the up position, which is the same as the Normal—Brakes Not Applied mode.

With the brake pedal still in the up position, the system enters the ATC Active mode when the ECU determines a rear wheel is starting to spin or lose traction and the traction control switch is in the TRACTION ENABLE or normal position.

For illustration purposes, let's assume that the right wheel is in a no traction mode below 31 mph.

As the right rear wheel begins to lose traction, the signal generated by its

***“The system enters the ATC Active mode when the ECU determines a rear wheel is starting to spin.”***

wheel sensor indicates the slippage to the ECU. When the ATC event is sensed by the ECU, it switches the states of the ATC valves and the ABS inlet and outlet valves to correct the traction problem.

With the ATC inlet valve now in the open state, and the ATC outlet valve in the closed state, the pressurized brake fluid is routed from the primary accumulator to the two pistons within the relay valve.

The pistons move, allowing the pressurized brake fluid from the accumulator to be routed to the four ABS inlet valves. With only the right rear wheel slipping, the ABS inlet valves for the left rear wheel and both front wheels are closed by the ECU. Meanwhile, the ABS inlet and outlet valves for the right rear wheel modulate to provide brake pressure.

***“When the ECU no longer senses any wheel slippage, the ATC and ABS valves are returned to their normal positions.”***

In this condition, pressurized brake fluid is routed only to the right rear wheel where it applies braking force to the slipping wheel. Since the differential tends to drive the wheel that presents the least resistance, more of the driving forces are shifted to the left rear wheel. When the ECU no longer senses any wheel slippage, the ATC and ABS valves are returned to their normal positions.

At the same time, the ATC warning light in the instrument cluster will be continuously lit to alert the driver that an ATC event is occurring.

If both rear axle wheels are spinning, the ECM intervenes by reducing the engine torque. Over 31 mph, no differential braking occurs; ATC events are controlled with engine torque only.

The position of the dash-mounted ATC switch is evaluated by the brake system ECU to control the sensitivity of ATC operation. Again, the ATC system is in the normal mode when the switch is moved to the TRACTION ENABLE position.

When the ATC switch is set to the DISABLE or MUD and SNOW position, the normal traction control feature is disabled. This mud and snow mode is also known as a “reduced sensitivity” mode, allowing a greater amount of wheel slippage in poor traction situations.

While in this mode, the indicator on the switch will be lit and the Traction Control indicator in the gauge cluster will be flashing.

If at any time, the brake travel switch is actuated, then ATC is terminated.

***“If both rear axle wheels are spinning, the ECM intervenes by reducing the engine torque.”***

## Conclusion

This concludes Program III of the Medium Duty Full Power Brakes series. Completion of this educational process is a key component towards International<sup>®</sup> technician certification. You are now required to take a post-test via ISIS<sup>®</sup>/Education/Service/Online testing.









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**Program IV:  
Basic Diagnostics &  
WABCO<sup>®</sup> TOOLBOX<sup>™</sup> Software**

**INTERNATIONAL<sup>®</sup>**



# Program IV: Basic Diagnostics & WABCO® TOOLBOX™ Software

The Full Power Brake system, unlike other computer-driven vehicle and engine systems, doesn't display fault codes on the instrument cluster.

Instead, the WABCO® TOOLBOX™ software is required to display brake related faults. It is a PC-based diagnostic program that is used to retrieve faults that have been logged by the ECU in the Full Power Brake system.

The software also provides repair instructions to fix any faults shown on the same computer screen. TOOLBOX™ also reports specific operating condition information, performs tests on individual components, and programs the ECU during the ECU replacement procedure.

Viewing this data, along with the fault code information, provides a distinct advantage during Full Power Brake diagnostics.

## Objectives

Participants will be able to:

- Identify, obtain, and run the software required to retrieve fault codes and service information from the system.

***“Viewing this data provides a distinct advantage during Full Power Brakes diagnostics.”***

It also allows the vehicle maintainer to schedule service intervals based upon the number of cycles for the various components, such as the number of times the pump motors have been cycled on and off.

The Meritor WABCO TOOLBOX™ Software User's Manual is available online at [www.meritorwabco.com](http://www.meritorwabco.com). Click on the link for TOOLBOX™ Software, then the User's Manual link.

Connect the EZ-Tech® to the vehicle's diagnostic connector.

Navigate to the WABCO® TOOLBOX™ Software. Click the HABS icon on the toolbar.

***“The menu bar and toolbar give you access to all TOOLBOX™ functions.”***

Turn the ignition to the ON position. The information from the ECU of the Full Power Brake system should appear in the corresponding boxes of this screen. The menu bar and toolbar, at the top of the screen, give you access to all TOOLBOX™ functions.

These functions allow you to gather information regarding repair, operational conditions, and programming of the Full Power Brake system. If you aren't sure of the purpose of each icon, slide your pointer over them and a message appears explaining their functions.

Click the ABS icon on the toolbar to retrieve any faults that have been logged by the ECU. The Fault Information window appears. This window provides a description of each fault, whether they are active or inactive, and related repair instructions appear at the bottom of the screen. In addition, you can clear, save, and update information within this screen.

Next, click the Display option on the menu to find information about the driving or vocational conditions of the vehicle. A menu bar drops down allowing you to click on the Counters option. The HPB Counters screen appears.

## **Conclusion**

This concludes Program IV of the Medium Duty Full Power Brakes series. Completion of this educational process is a key component towards International® technician certification. You are now required to take a post-test via ISIS®/Education/Service/Online testing.

***“The Fault Information window provides a description of each fault.”***







A NAVISTAR COMPANY

# **Program V: Common Service Procedures**

**INTERNATIONAL<sup>®</sup>**





# Program V: Common Service Procedures

## Section 1: Shop Safety

Before beginning work on the Full Power Brake system, keep in mind that this is a sophisticated and complex, computer-driven brake system that uses state-of-the-art components.

Be sure that the procedures shown in this training program are followed precisely. Also keep in mind that safety and environmental concerns are critical.

Be sure to follow each warning, caution, and note as they are presented throughout this training series.

Warnings indicate procedures and safety measures that must be followed precisely to avoid serious personal injury or death of yourself and other shop personnel and to avoid damage to the vehicle, equipment, or components.

Cautions indicate a procedure that you must follow exactly to avoid equipment or component damage.

Notes indicate operations, procedures, or instructions that are important for proper service.

### Objectives

Participants will be able to:

- Follow safety instructions.
- Identify tools required for repair.
- Identify the need for and effectively perform system depressurization, bleeding, and repressurization.

### NOTE

**Throughout this program the HCU shown may have features not currently available on all vehicles.**

**WARNING**

**Don't allow brake fluid to contaminate brake pads. Brake fluid contamination on brake pads could result in reduced braking.**

Handle HCU's and spare parts with care and attention. Don't use compressed air to blow out hydraulic ports before installation on the vehicle.

Don't allow brake fluid to come into contact with your eyes or skin.

Before working on the brake system, thoroughly clean all bleeder screws and the master cylinder cap. Only use new specified DOT 3 or DOT 4 brake fluid from a sealed container to refill the system and to lubricate parts. Refer to ISIS<sup>®</sup> for the proper fluid specification.

Use extreme caution when handling brake fluid. Brake fluid is corrosive and damaging to painted surfaces.

During bleeding procedures, the brake fluid level must not fall below the MIN mark on the master cylinder reservoir. Regularly check and fill the master cylinder as components are bled.

**WARNING**

**Whenever performing procedures that require the batteries to be disconnected, always disconnect the main negative battery cable first. When reconnecting, always connect the main negative battery cable last.**

Failure to maintain the MIN level could result in more air entering the system, making it impossible to bleed the system. Also, be careful not to overfill the master cylinder. Overfilling can lead to spills when fluid in the accumulators is returned to the master cylinder during depressurization.

**WARNING**

**Before beginning diagnostic or service procedures, always shift the transmission to park or neutral, set the parking brake, and block the wheels.**

After completing all desired brake service, test the brakes for function and inspect the system thoroughly for leaks.

When performing service work of any kind always protect the interior of the vehicle by using a paper floor mat, a steering wheel cover, and a seat cover.

When working on the brake system, keep the work area and tools as clean as possible. Also, clean all connections or fittings before disconnecting or removing components. Use a suitable pan to catch any fluid when disconnecting components.

All openings should be immediately plugged during removal and remain so until reinstallation to prevent the entry of dirt or other foreign material and to prevent unnecessary loss of fluid.

Be sure that you know the location of properly rated and charged fire extinguishers.

Be sure you know the location of an emergency eyewash station.



## WARNING

**While servicing an ATC-equipped vehicle, the ATC system MUST be disabled before operating the vehicle with only one drive wheel lifted off the ground. Performing this operation on a vehicle with an active ATC system may result in the vehicle moving and falling from the jack stand as power will be transferred to the wheel that is still on the ground.**



## WARNING

**The ATC system CANNOT be disabled by placing the dash mounted switch in the DISABLE position. The ATC system can be temporarily disabled using TOOLBOX™ Software. Use extreme caution. When the ATC system is disabled using TOOLBOX™ Software, it will remain disabled only until the next ignition cycle. The TOOLBOX™ screen indicates when the ATC function is disabled.**

**WARNING**

**Always provide ventilation when operating an engine in an enclosed area. Inhalation of exhaust gas can be fatal.**

**WARNING**

**When working on the brake system, always wear safety glasses with side shields and chemical-blocking nitrile gloves.**

## Section 2: Required Tools & Bleeding Methods

International<sup>®</sup> 4000 Series service requires basic hand tools as well as the following special tools and supplies:

- the EZ-Tech<sup>®</sup>
- the EZ-Tech<sup>®</sup> Link or interface cable
- one Master Cylinder Cap Adapter ZTSE4678
- calibrated torque wrenches
- one clean, graduated glass or plastic bottle or receptacle
- one transparent rubber or plastic bleed hose
- a suitable crow's foot adapter to torque bleeder screws and break lines
- sufficient supply of new DOT 3 or DOT 4 brake fluid from a sealed container
- a steel band clamp wrench
- proper bleeding equipment

Any of the following three types of bleeding procedures may be used: Fluid Over Fluid, Air Over Fluid, or Dry Nitrogen Over Fluid.

If the Fluid Over Fluid bleeding procedure is used, pressurized fill and bleed equipment is required.

If the Air Over Fluid is used, the Air Over Fluid Bleeder Tool ZTSE4757-2 is required.

## **Fluid Over Fluid**

This type provides brake fluid under pressure from an external tank to the master cylinder reservoir. Shop air is used to pressurize the bleeder tank.

Keep in mind that the following procedure must always be followed when using a Fluid Over Fluid pressure bleeder.

Check that the pressure bleeder has an adequate supply of brake fluid.

Pressurize the unit to 35 psi and bleed any air from the unit.

Connect the cap adapter to the master cylinder reservoir.

***“Any of the following three types of bleeding procedures may be used.”***

## **Air Over Fluid**

This type pressurizes the master cylinder reservoir with clean, dry, regulated shop air.

This pressurization method uses the reservoir cap adapter and the Air Over Fluid Bleeder Tool ZTSE4757-2. It has an inline disposable filter, a non-adjustable pressure regulator set at approximately 35 psi, a pressure relief valve, hosing, and a mounting hook.

Keep in mind that the following procedure must always be followed when using this Air Over Fluid method.

Connect the cap adapter to the master cylinder reservoir.

Connect the bleeder tool assembly to shop air and also to the reservoir cap adapter.

## **Dry Nitrogen Over Fluid**

This type pressurizes the master cylinder reservoir with regulated dry nitrogen.

Keep in mind that the following procedure must always be followed when using this Dry Nitrogen Over Fluid method.

Connect the cap adapter to the master cylinder reservoir.

Connect the dry nitrogen hose to the reservoir cap adapter, and adjust the pressure to 35 psi.

Any time a Full Power Brake system circuit must be opened for service, it must be fully depressurized first. Then, a bleeding process must be performed to complete the repair. Since these two procedures are a vital part of almost every Full Power Brake repair, they are covered first. Then, as each repair process is outlined, we refer back to these essential depressurization and bleeding procedures.

Also, any time accumulators are replaced as a part of brake service, a special depressurization and disposal procedure must be performed on each accumulator, unless it is being replaced under warranty.

### **Section 3: System Depressurization**

Be sure the key is in the OFF position.

Start by removing the two brake system pump motor 30 amp fuses in the power distribution center, located near the master cylinder.



#### **WARNING**

**Opening brake system circuits for service means the brake system must be fully depressurized. Always perform brake service on a level surface with the wheels blocked using wheel chocks.**



#### **WARNING**

**The Full Power Brake system is a pressurized system that reaches more than 2300 psi. This pressure is not reduced when the ignition is turned to the OFF position. Fully depressurize the system before servicing the brakes.**

Verify that the brake fluid level in the master cylinder is at the MAX mark.

Connect the EZ-Tech<sup>®</sup>, set the ignition key to ON, start the EZ-Tech<sup>®</sup> and open the TOOLBOX<sup>™</sup> program.

Depressurize the system by depressing the brake pedal a minimum of 30 times.

Use TOOLBOX<sup>™</sup> to verify that the pressure at both accumulators is at zero psi.

Turn the ignition key OFF. Disconnect the battery and ECM negative cable.

The system is now ready for servicing.



## WARNING

**Batteries expel explosive gases. Keep sparks, flames, cigarettes, or other ignition sources away at all times.**

## NOTE

**Cover all electrical connectors near the bleeder screws to make absolutely certain no brake fluid enters the terminals or plugs.**

## Section 4: Pressure Bleeding Procedures

The following pressure-bleeding procedures are required any time the master cylinder circuit or the HCU-to-caliper circuit is opened, using either the Fluid Over Fluid, Air Over Fluid, or Dry Nitrogen Over Fluid methods.

Because the master cylinder system is isolated from the HCU-to-Caliper system, brake pedal bleeding is an unacceptable technique when servicing the International<sup>®</sup> 4000 Series Full Power Brake system.







## WARNING

**Failure to properly bleed the system whenever any hydraulic system fitting is loosened or disconnected will allow air to remain in the system. Air in hydraulic lines will greatly reduce the pressure available for braking. This can increase vehicle stopping distance.**



## CAUTION

**Prior to working on the braking system, all bleeder screws and the master cylinder cap must be cleaned thoroughly. Cleanliness of fluid and areas around the service points has to be maintained. Don't use mineral oil based fluid for cleaning. Mineral oil based fluid can contaminate brake fluid and could damage the interior of the components and cause a system malfunction.**

When using one of the pressure bleeding methods, it is very important that the procedures be followed precisely because air remaining in the HCU-to-caliper circuit may not be indicated by the feel of the brake pedal.

If the master cylinder or master cylinder reservoir has just been replaced, then both circuits of the master cylinder must be bled by opening the two bleeder screws at the HCU relay valve.

If the HCU or the HCU reservoir has been replaced, then the entire system must be bled. You must bleed the master cylinder circuit first, followed by the HCU-to-calipers circuits, starting first with the longest circuit from the HCU assembly and finishing with the shortest circuit.

For demonstration purposes, we will use the Fluid Over Fluid method. As mentioned previously, the two Air Over Fluid options are also appropriate methods for bleeding the brakes.

Add brake fluid and then pressurize the pressure tank with shop air. Connect the Reservoir Cap Adapter ZTSE4678 to the master cylinder reservoir and be sure it is securely tightened. Hook the pressurized tank hosing to the cap adapter and maintain a pressure in the bleeder of 35 psi.

Fit a hose onto one of the master cylinder bleeder screws and submerge the free end of the hose into the bleed bottle. Open the bleeder screw until the fluid begins to flow. After draining a minimum of 8.5 oz. of fluid, check the stream for air bubbles. When no further air bubbles are observed, close the screw.

Repeat these steps with the second master cylinder bleeder screw, located at the relay valve. Remove the bleeder hose and torque the bleeder screws. Refer to ISIS<sup>®</sup> for the appropriate torque specification.

If the HCU-to-caliper circuits are to be bled, complete this process now.

## **Section 5: Repressurizing the System**

Reconnect the batteries.

Reinstall the two pump motor fuses.

Turn the ignition ON. The HCU pump motors will start running for about 45 seconds. This will fill the accumulators and pressurize the system.

The following Deplete Accumulators procedure is required after a caliper circuit or the HCU has been opened.

***“This Deplete Accumulators procedure is not required if only the master cylinder circuit has been opened, serviced, and then bled.”***

For example, this process is required after opening the HCU and replacing one or both pumps. This Deplete Accumulators procedure is not required if only the master cylinder circuit has been opened, serviced, and then bled.

Using the EZ-Tech<sup>®</sup> and the TOOLBOX<sup>™</sup> program, select the Deplete Accumulators function from the EOL pull down menu. This function helps clear air from the system by depressurizing and repressurizing both accumulators. A dialog box will indicate when the function is complete.

If the vehicle is not equipped with ATC, you must perform this step with the brake pedal fully depressed throughout the duration of this Deplete Accumulators procedure. Failure to do so will prevent the accumulators from being depleted.

Release the pressure from the brake bleeder unit. Remove the bleeder equipment from the master cylinder reservoir.

If the Deplete Accumulators procedure was just performed because a caliper circuit was opened or the pumps were replaced, run this procedure again. Select Deplete Accumulators from the EOL pull down menu.

Again, if the vehicle is not equipped with ATC, you must perform this step with the brake pedal fully depressed throughout the procedure. Again, if only the master cylinder circuit was opened, serviced, and bled, this step does not need to be performed.

***“If only the master cylinder circuit was opened, serviced, and bled, this step does not need to be performed.”***

Check to make sure that the fluid in the reservoir is between the MIN and the MAX mark. Reinstall the master cylinder reservoir cap.

Using the EZ-Tech<sup>®</sup> and the TOOLBOX<sup>™</sup> program, clear all brake system related inactive fault codes since codes may have been set while disconnecting and reconnecting power to the system.

To make the necessary repairs when active fault codes are indicated, refer to Section 5, Diagnostics and Troubleshooting within the Full Power Hydraulic ABS Brake System Service Manual, located on ISIS<sup>®</sup>.

If the HCU pump motors fail to deliver a sufficient amount of fluid, the ECU will control the HCU pump motors in a self-priming procedure. In this case, the HCU pump motors should stop within 3 minutes, with the brake warning light and buzzer off.

If this is not the case, meaning one or both pumps do not prime, re-perform the Deplete Accumulators function previously described. Upon completion, both accumulators should be fully charged as indicated on the TOOLBOX™ screen.

If an accumulator is still not charging correctly, refer to Section 5, Diagnostics and Troubleshooting found on ISIS® to make the necessary repairs.

Check the system for leaks and test the operation of the brake system.



## WARNING

**If a leakage is noted in the system, before any repairs are attempted, the system MUST be depressurized BEFORE making any repairs.**

## Conclusion

This concludes Program V of the Medium Duty Full Power Brakes series. Completion of this educational process is a key component towards International® technician certification. You are now required to take a post-test via ISIS®/Education/Service/Online testing.









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# **Program VI: Repair Procedures**

**INTERNATIONAL<sup>®</sup>**



# Program VI: Repair Procedures

## Section 1: Accumulator Disposal Procedures

If the accumulator is defective, check warranty status first. Accumulators still under warranty must be returned without depressurizing. Drilling the accumulators will void the warranty. Contact ArvinMeritor OnTrac at 866-668-7221 for instructions.

If the accumulator is not under warranty, it will need to be depressurized before it can be safely discarded.

Securely clamp the accumulator in a drill press vise. The drilling point will be on the opposite side of the welded seam from the threaded port.

Center-punch the accumulator at the location to be drilled.

Using an 1/8-inch drill bit, slowly and carefully drill through the accumulator.

After the internal pressure is released, the accumulator may be scrapped.

### Objectives

Participants will be able to:

- Determine if components need to be returned under warranty.
- Dispose of accumulators not under warranty.
- Repair all serviceable components.



### WARNING

**The accumulator must be positioned correctly and securely in a drill press vise to prevent it from moving.**



### CAUTION

**Any liquid spilled or drained from the accumulator should be treated as waste brake fluid and must be disposed of properly.**

## Section 2: Accumulator Replacement

### NOTE

**Accumulators have a limited shelf life. Do not use components beyond the expiration date.**

If the accumulator has failed, it will be indicated by TOOLBOX™ Software diagnostics. It is recommended that when one accumulator fails, the remaining one should be replaced as well.

Depressurize the system according to the procedures demonstrated in Program V of this series.

Use clamping pliers to pinch off the low-pressure hose to the reservoir, being careful not to damage the reservoir inlet.

Carefully clean the area around the HCU.

Position a container to collect the fluid drained when performing the next step.

Using a strap wrench, remove both accumulators from the HCU.

Plug the counter bores to ensure that no contaminants will enter the HCU.

Check warranty status first. Accumulators still under warranty must be returned without depressurizing. If the accumulator is not under warranty, it

will need to be depressurized before it can be safely discarded.

Remove a plug from one of the counter bore areas of the HCU and one of the plugs from an accumulator.

Make sure the O-ring is installed on the accumulator and has been lubricated with clean brake fluid.

Reinstall one of the accumulators and tighten it by hand until it's snug. Next, tighten the accumulator using a torque wrench with a strap wrench attachment. This wrench should be an 18–24 inch long torque wrench. Torque to the specifications found in ISIS<sup>®</sup>.

Reinstall the second accumulator by repeating the previous steps.

Remove the clamp pliers from the low-pressure hose.

Check to make sure that the fluid in the reservoir is between the MIN and the MAX mark.

Next, complete the procedure entitled "Repressurizing the Full Power Brake System," covered previously in Program V of this series.

***“Make sure the O-ring is installed on the accumulator and has been lubricated with clean brake fluid.”***

## Section 3: ECU Replacement

The TOOLBOX™ Software detects a failed ECU. Like the accumulator, the ECU has a limited shelf life. Be sure that the replacement part has not expired.



### CAUTION

**To prevent damage to the ECU due to electrostatic discharge, always disconnect the battery before servicing the ECU.**

Also, be aware that the ECU has various programmable parameters that can vary according to the vehicle wheelbase and configuration. The default parameter settings are programmed at the factory. To ensure that a replacement ECU has the correct settings, use only the correct replacement number. Then refer to ISIS® to properly complete the programming of the replacement ECU.

Disconnect the battery.

Carefully clean the outside of the HCU.

Unlatch and disconnect both electrical connectors from the back of the ECU.

Remove the four screws that secure the ECU to the HCU.

Any damage to these items requires that a new HCU be installed. In addition, carefully pull the ECU straight away from the HCU to prevent damage to the ABS and ATC solenoid valves that protrude from the HCU.



### CAUTION

**Do NOT touch the two connectors serving the pressure sensors. They are very sensitive and can be damaged from a static electricity discharge. Also, these two pressure and the ten solenoid valves (two ATC and eight ABS) are not serviceable components.**

Remove the ECU.

Carefully wipe the area surrounding the solenoid valve which was covered by the ECU. Don't touch the two pressure sensors.

Remove and discard the two orange seals from the two pressure sensors.

A new ECU service kit consists of an ECU module, two orange seals for the pressure sensor and four new mounting screws.

Assemble the new orange pressure sensor seals into the new ECU module.

Carefully position the ECU module over the HCU valves and seat it by pressing simultaneously on all sides. Ensure that the pump motor connectors achieve full depth into the HCU before inserting the screws.

The gap between the HCU body and ECU module housing should be about eight thousandths of an inch. If this gap cannot be achieved, remove the ECU module, check for obstructions, verify that the seals are correctly installed, and reinstall the ECU.

Install the four mounting screws. Tighten in a crossing pattern to the specified torque found in ISIS<sup>®</sup>. Verify

## NOTE

**The ECU has a limited shelf life. Do not use beyond the expiration date.**



## WARNING

**Ensure that the ECU connectors are properly installed and latched to prevent them from becoming disconnected. Failure to securely connect and latch the ECU connectors could result in loss of braking functions during vehicle operation.**

that the metal sleeves of the ECU module housing rest flat on the HCU body.

Connect and secure the ECU module connectors by engaging the latches.

Route and secure the wiring harness in the factory location.

Reconnect the battery.

Using the EZ-Tech<sup>®</sup> and TOOLBOX<sup>™</sup>, program the replacement ECU to match the VIN.

Finally, test the brake system.

## Section 4: Relay Valve Replacement

Depressurize the system as previously discussed.

Use a clamp to pinch the low-pressure hose at the inlet to the HCU reservoir. Place the clamp midway between the HCU reservoir inlet and the crossmember, being careful not to damage the reservoir inlet.

In some vehicle applications the rubber section of the low-pressure hose is too short to provide a leakproof clamp at this location.



## CAUTION

**If the relay valve assembly is to be reused, no rubber or other material must be allowed to enter the orifices on the top of the assembly.**



If necessary, clamp the low-pressure hose close to the master cylinder outlet. Carefully clean the relay valve assembly and the area around it.

Disconnect both master cylinder brake lines from the relay valve assembly on the HCU. Plug the lines and position them out of the way.

Using a 4 mm Allen wrench, remove the five screws securing the relay valve assembly and then carefully remove it from the HCU.

Remove the rubber coated relay valve seal plate. Bend the seal plate to prevent re-use, and discard.

Position a new seal plate on the relay valve by inserting two mounting screws into the relay valve assembly. In order for the screws to protrude through the relay valve, they must be held with Allen wrenches or other tools.

Using the screws as a guide, position the new, clean seal plate onto the top of the relay valve assembly.

Position the relay valve assembly against the bottom of the HCU and thread the two screws into the HCU. Finger tighten only.



## CAUTION

**If it is necessary to clean the mating surfaces of the HCU and relay valve assembly, use denatured alcohol and a lint-free cloth.**



## CAUTION

**The relay valve seal plate must be positioned with the orientation tab in the correct location, AND the mounting screw holes aligned with those in the relay valve assembly.**



## CAUTION

**A new seal plate is ALWAYS required during the following procedure.**

Install the remaining three mounting screws, and torque all five screws in a two-step process according to the specifications found on ISIS<sup>®</sup>.

Connect the master cylinder brake lines to the relay valve assembly. Torque these fittings to the specifications found on ISIS<sup>®</sup>.

Bleed the master cylinder circuits as discussed previously in Program V of this series.

## **Section 5: Wheel Speed Sensor Replacement**

Cut the tie straps that hold the sensor cable to other components.

Disconnect the sensor cable from the chassis harness.

Clean the area surrounding the sensor to prevent contamination.

Remove the sensor from the spring clip by twisting and pulling on the sensor. Don't pull on the sensor by the cable.

Remove the sensor and cable assembly.

Remove and inspect the spring clip and replace it, if it is damaged.

---

Clean the area where the wheel sensor will be installed.

If a new spring clip is being installed, lubricate it with an approved lubricant. Refer to ISIS® for the specification.

Push the spring clip into the wheel end bracket until it stops.

Lubricate the sensor.

Push the sensor completely into the spring clip until it contacts the tooth wheel.

Reconnect the sensor cable to the chassis harness.

Reconnect the sensor harness with new tie straps.

Clear fault codes from the ECU.

Finally, test the brake system.

## **Section 6: Master Cylinder Reservoir Replacement**

Depressurize the system according to the procedures demonstrated in Program V of this series.

Disconnect the travel switch wiring on the master cylinder and the fluid level switch on the master cylinder reservoir.



## CAUTION

**Before performing the following steps you will need a suitable container that can hold at least 1 gal. of fluid.**

Carefully clean the outside of the master cylinder reservoir.

Use clamp pliers to pinch the low-pressure hose near the outlet of the master cylinder reservoir, being careful not to damage the reservoir outlet.



## CAUTION

**During the following procedure, do not depress the brake pedal unless instructed to do so.**

Remove the cap on the master cylinder reservoir.

Disconnect the low-pressure hose from the master cylinder reservoir. Allow the fluid to drain. Plug the low-pressure hose to prevent contamination.

**FULL POWER BRAKE FACT:**  
Because of the master cylinder reservoir design, not all of the brake fluid will be able to be drained. Keep this in mind as you are handling the reservoir.

Remove the nut securing the reservoir to the master cylinder bracket.

Remove the two roll pins securing the reservoir to the master cylinder.



## CAUTION

**Before performing the following step, care must be taken to protect the reservoir mounting tabs from excessive deflection when removing the roll pins. One method is to back up the mounting tab with a socket or similar object that will allow the pins to be driven through the tab without deflecting the tab.**

Lift the reservoir off of the master cylinder. Some resistance will be felt because of the rubber seals between the master cylinder and the reservoir.

Verify that the two rubber seals were removed from the master cylinder with the reservoir.

Plug the master cylinder ports to ensure that no contamination will enter.

Carefully clean the top of the master cylinder.

Install two new black rubber seals into the ports on the top of the master cylinder.

Lubricate the reservoir seals with new brake fluid.

Install the new reservoir by placing it on the mounting bracket stud and carefully pivoting it downward to seat it fully onto the master cylinder seals.

Install the two roll pins that attach the reservoir to the master cylinder.

Install the nut to attach the reservoir to the bracket.

Release the pliers from the low-pressure hose.

Secure the low-pressure hose to the master cylinder reservoir outlet.

Connect the travel switch and the fluid level switch wiring on the master cylinder.

Fill the reservoir to between the MIN and MAX mark with new brake fluid.

Then, bleed the master cylinder circuit according to the procedures demonstrated earlier in Program V of this series.



## CAUTION

**Before performing the following step, care must be taken to protect the reservoir mounting tabs from excessive deflection when installing the roll pins. One method is to back up the mounting tab with a socket or similar object that will allow the pins to be driven through the tab without deflecting the tab.**

## Section 7: Master Cylinder Replacement

### NOTE

**The master cylinder has a limited shelf life. Do not use beyond the expiration date.**

Depressurize the system according to the procedures demonstrated in Program V of this series.

Disconnect the travel switch wiring on the master cylinder and the fluid level switch on the master cylinder reservoir.



### CAUTION

**Before performing the following steps you will need a suitable container that can hold at least 1 gal. of fluid.**

Use clamp pliers to pinch the low-pressure hose near the outlet of the master cylinder reservoir, being careful not to damage the reservoir outlet.

Remove the cap on the master cylinder reservoir.



### CAUTION

**During the following procedure, do not depress the brake pedal unless instructed to do so.**

Disconnect the low-pressure hose from the master cylinder reservoir. Allow the fluid to drain. Plug the low-pressure hose to prevent contamination.

Disconnect the two brake tubes from the master cylinder. Plug the brake line tubes and the master cylinder ports.

**FULL POWER BRAKE FACT:** Because of the master cylinder reservoir design, not all of the brake fluid will be able to be drained. Keep this in mind as you are handling the reservoir.

Disconnect the master cylinder push rod clevis from the brake pedal by removing the clevis pin and spring retainer. Unbolt the master cylinder reservoir from the mounting bracket.

Unbolt the master cylinder from the mounting bracket.

Remove the master cylinder and reservoir from the bracket.

Install the master cylinder reservoir assembly so that the stud on the bracket is inserted into the hole of the reservoir mounting tab.

The master cylinder base slips over the two mounting studs on the cowl and the master cylinder clevis passes through the hole in the cowl.

Reinstall the mounting nuts, securing the master cylinder base and the reservoir to the bracket.

Connect the master cylinder push rod clevis to the pedal assembly using the clevis pin and the spring retainer. Lock the spring retainer.

Connect the primary and secondary brake tubes to the master cylinder. Torque to the specifications in ISIS®.

Connect the low-pressure hose to the master cylinder reservoir using the existing hose clamp.

Connect the travel switch and the fluid level switch on the master cylinder.

Fill the reservoir to between the MIN and MAX mark with new brake fluid.



## WARNING

**The travel switch must be connected on the master cylinder to ensure that the brake system ABS functions operate correctly.**

Then, bleed the master cylinder circuit according to the procedures demonstrated in Program V of this series.

## **Section 8: Master Cylinder Travel Switch Replacement**

***“The travel switch on the master cylinder can be removed without opening the brake fluid system.”***

The travel switch on the master cylinder can be removed without opening the brake fluid system. Therefore, the switch can be replaced without depressurizing the brake system.

Disconnect the master cylinder brake pedal travel switch wiring.

Remove the two screws securing the switch to the master cylinder and pull the switch straight down.

Position the replacement switch and seal so the mounting holes align with the holes on the master cylinder body. Secure the switch with two mounting screws.

Connect the wiring to the master cylinder travel switch.

## **Section 9: Fluid Level Switch Replacement**

The fluid level switch is located on the bottom of the master cylinder reservoir. The switch can be removed



without opening the brake fluid system. Therefore, it can be replaced without depressurizing the system.

Disconnect the fluid level switch wiring.

On the opposite end of the switch body from the electrical connector, squeeze the lock tabs and push the switch out of its holder tube.

Push the replacement switch into the holder tube until the locking tabs expand to hold the switch in place.

Connect the wiring to the switch.

Verify that the switch operates by checking the dash warning light condition against the level in the master cylinder.

## **Section 10: HCU Pump Replacement**

Both pumps are located in cavities in the HCU, and are accessed from the bottom. The retaining plug for the secondary system pump is visible on the bottom of the HCU. This pump is located near the front of the HCU, but pressurizes the rear axle brake system.

The retaining plug for the primary system pump is located under the relay

***“... it can be replaced without depressurizing the system.”***

***“The relay valve assembly must be removed to access the primary pump.”***

valve assembly. This pump pressurizes the front axle brake system.

The relay valve assembly must be removed to access the primary pump. This procedure is covered earlier in this program. This can be done without disconnecting the master cylinder brake lines. Therefore, it is not necessary to bleed the master cylinder circuit after performing this procedure.

If both HCU pumps are being replaced, replace the secondary pump first.

After either a single or double pump replacement, be sure to complete the Deplete Accumulators procedure during repressurization, demonstrated in Program V of this series.

Depressurize the system as discussed previously in Program V of this series.

Use a clamp to pinch the low-pressure hose at the inlet to the HCU reservoir. Place the clamp midway between the HCU reservoir inlet and the crossmember, being careful not to damage the reservoir inlet.

In some vehicle applications the rubber section of the low-pressure hose is too short to provide a leakproof clamp at this location. If necessary, clamp the

low-pressure hose close to the master cylinder outlet.

Unlatch and disconnect both wiring connectors from the ECU module, and position the loose harnesses out of the way.

Carefully clean the bottom surface of the HCU. Be careful not to contaminate the connectors or pins of the ECU.

Prepare a replacement pump for installation by lubricating both O-rings with clean brake fluid and then by actuating the pump several times by depressing the spring-loaded pump button by hand.

The initial force required to actuate the pump may be high. After the first actuation, the force required to depress the button should be reduced.

Using a 6 mm Allen wrench, remove the secondary pump retaining plug from the HCU.

Using clean needle nose pliers (with a good grip), remove the secondary pump from the bore. Allowing the pliers to slip could create metal shavings that must be removed.

## NOTE

**A new seal plate is included with a new pump.**



## CAUTION

**The condition of the pump bore is very important. Do not allow tools to damage the surface of the bore.**



## CAUTION

**Do not damage the pump O-rings while installing the replacement pump. The O-rings must be lubricated with clean brake fluid.**

## NOTE

**To minimize the amount of brake fluid spilled, insure that the replacement pump is prepared and within reach before removing the pump.**

Immediately install the replacement pump. Carefully seat the pump into the bore, using light hand pressure only.

Verify that the retaining plug is clean. Then install the plug and torque it to the specifications found on ISIS<sup>®</sup>.

Clean any brake fluid from the surface of the HCU.

If the primary pump is also being replaced, proceed directly to the Primary HCU Pump Replacement Procedure. If the primary pump doesn't need to be replaced, complete the following steps.



## WARNING

**Ensure that the ECU connectors are properly installed and latched to prevent them from becoming disconnected. Failure to securely connect and latch the ECU connectors could result in loss of braking functions during vehicle operation.**

Attach the two electrical connectors to the HCU ECU. Secure the connectors by engaging the latches.

Remove the clamp or clamps used to pinch the low-pressure hose during removal.

If the secondary pump is the only pump being replaced, be sure to complete the Deplete Accumulators steps covered earlier in Program V of this series.

Remove the relay valve assembly from the HCU, but do NOT disconnect the master cylinder brake lines. Refer to the Relay Valve Replacement in Section 4 of this program.

Taking care not to kink or bend the brake lines, reposition the relay valve assembly (with the brake lines attached) to allow access to the bottom of the HCU.

Prepare and install the replacement pump according to the Secondary Pump Procedures demonstrated earlier in this program.

Install the relay valve assembly. Refer to the Relay Valve Replacement Procedures earlier in this program. Perform the Deplete Accumulators steps of Program V in this series.

## Section 11: HCU Removal

The HCU must be replaced if any of the following components are faulty:

- the electric motors
- the pressure sensors
- the ABS or ATC solenoid valves

Although a bad electric motor requires HCU replacement, pumps alone can be replaced separately.

In addition to these components, the HCU also includes a new reservoir and a new ECU. As an alternative, a Reservoir Kit and ECU Kit can be

### NOTE

**When moving the relay valve assembly to gain access to the primary pump, do NOT disconnect the master cylinder brake lines. If these lines are disconnected, the master cylinder circuit must be bled as indicated in the Relay Valve Assembly Installation procedures.**



### CAUTION

**A new seal plate is always required when installing the relay valve assembly.**

purchased separately. The relay valve can also be replaced separately.

The HCU doesn't include an Accumulator Kit or the HCU Assembly Mounting Brackets.

Keep in mind that the HCU assembly must be removed when servicing the HCU reservoir to prevent contamination of the system.

It is also required due to limited clearance between the top of the HCU reservoir and the bottom of the truck body.

Depressurize the system according to the procedures demonstrated in Program V of this series.

Carefully clean the area around the HCU, including the outside of the HCU itself.

Unlatch and disconnect the wiring to the ECU.

Using clamping pliers, pinch off the low-pressure hose to the reservoir.

Position a container to collect the fluid drained when performing the next step.

Using a strap wrench, remove both accumulators from the HCU. By doing



## CAUTION

**Any form of contamination entering the system could prevent the system from operating correctly. Thoroughly clean the area around the fittings before disconnecting them. Always plug open ports and lines as quickly as possible.**

## NOTE

**The HCU has a limited shelf life. Do not use components beyond the expiration date.**

this you will gain easier access to the brake lines and reduce the weight of the HCU assembly.

Plug these counter bores to ensure that no contaminants will enter the HCU. Also, plug the ports on the accumulators and retain them for reinstallation.

Using a backup wrench, secure each port fitting that is threaded into the HCU while you use a second wrench to disconnect the six brake line fittings.

Be sure to protect the tubes and also the port fittings on the HCU by covering them with a properly sized plug until reinstallation.

Disconnect the low-pressure hose from the HCU reservoir.

Plug the low-pressure hose and the reservoir inlet to prevent contamination and fluid loss during removal of the HCU.

To allow easier removal of the HCU, loosen the two bolts securing the HCU mounting bracket to the frame rail. The bolts should be left in place, but must be loose enough to allow movement of the mounting bracket.

***“Be sure to protect the tubes by covering them with a properly sized plug.”***

Remove the four mounting brackets bolts.

Remove the HCU by sliding it downward.

Retain the mounting hardware including four bolts and four bushings for use with the replacement HCU.

Move the HCU assembly to a clean workbench.

## Section 12: HCU Reservoir Replacement (Bench-Top)

Remove the four screws securing the reservoir to the main body of the HCU.

Carefully lift the reservoir away from the HCU, being sure you don't introduce any dirt into the HCU ports.

Some resistance will be felt during this procedure due to the four rubber grommet seals between these two components.

Verify that all four grommet seals have been removed from the HCU ports and then discard them along with the failed reservoir.

Use an HCU Reservoir Kit to replace the reservoir or a Rubber Grommets Kit



### CAUTION

**Since you will be reusing the HCU, it is critical that the HCU is thoroughly cleaned, including all areas between the HCU main body and the HCU reservoir. Failure to properly clean the HCU will introduce contamination and may lead to overall failure of the Full Power Brake system once the HCU is reinstalled.**



if the reservoir is determined to be OK and only the grommets have failed.

Remove the protective plugs and then install the new grommet seals into the top of the HCU ports, being sure to lubricate these seals with new brake fluid prior to installation.

Install the reservoir by pressing it carefully and fully into the grommet seals, making sure the reservoir's inlet is oriented toward the front side of the truck.

Install the four mounting screws and torque to the specifications in ISIS<sup>®</sup>.

Fill the reservoir with about two quarts of new brake fluid and then cap the reservoir.

Proceed to HCU Installation.

## Section 13: HCU Installation

Place the four bushings into the HCU holes in both HCU mounting brackets, two per bracket. The stepped bushings are pushed into the holes from the inside surface of the bracket.

Position the HCU between the mounting brackets and secure it using two bolts per bracket. Verify that the mounting bushings remain in place.



### CAUTION

**Don't remove any of the protective caps of the HCU until the HCU is ready to be connected.**

Tighten the two bolts that secure the HCU mounting bracket to the frame rail that were loosened previously.

Connect the low-pressure hose to the HCU reservoir and secure it with a hose clamp.

Connect the brake lines to the HCU and torque to the specifications found in ISIS®.

Remove a plug from one of the counter bore areas of the HCU and one of the plugs from an accumulator.

Make sure the O-ring is installed on the accumulator and has been lubricated with clean brake fluid.

Reinstall one of the accumulators and tighten it by hand until it's snug. Next, tighten the accumulator using a torque wrench with a strap wrench attachment. This wrench should be an 18–24 inch long torque wrench. Torque to the specifications found on ISIS®.

Reinstall the second accumulator by repeating the previous steps.

Remove the clamp pliers from the low-pressure hose.

Secure the two electrical connectors to the ECU by engaging the latches.



## WARNING

**Ensure that the ECU connectors are properly installed and latched to prevent them from becoming disconnected. Failure to securely connect and latch the ECU connectors could result in loss of braking functions during vehicle operation.**

Fill the reservoir to between the MIN and MAX marks with new brake fluid.

Bleed the master cylinder circuit HCU-to-caliper circuits and depressurize the system according to the procedures demonstrated in Program V of this series.

## **Section 14: Parking Brake Inspection & Drum Removal**

Remove the drive shaft and support it with a jack stand.

Remove the park brake drum.

Inspect the brake shoes. Replace the linings if there is uneven or excessive wear, cracks, warping, or the linings have been worn to less than 1/32 of an inch above the shoes.

Replace the brake shoes if they are contaminated with grease, fluids, or other foreign substances.

Inspect the brake lever, cam, springs, hold down pins, adjuster nut, and the star wheel for cracks, excessive wear, or bends.

Inspect the adjuster cable assembly, adjuster nut and screw for damage or wear. Replace any worn or damaged parts.



### **CAUTION**

**Keep grease and other foreign materials away from the brake shoe linings and drum surfaces. Contamination of shoe linings or the drum may result in damage to the brake linings.**

***“Replace the drum if it has uneven wear, deep grooves, excessive run-out or the measurement is not within specifications.”***

Inspect the brake drum, replace the drum if it has uneven wear, deep grooves, excessive run-out or the measurement is not within specifications.

### **Section 15: Parking Brake Shoe Adjustment (Drum Installed)**

Raise the rear axle.

Insert a brake adjusting tool or a flathead screw driver into the parking brake adjusting hole and move the star wheel teeth down to expand the brake shoes. Continue adjusting until the drum cannot be turned.

Move the star wheel teeth up to retract the shoes until the drum just begins to run freely without any drag from the linings.

Lower the vehicle.

Test the operation of the parking brake.

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## Conclusion

This concludes Program VI of the Medium Duty Full Power Brakes series. Completion of this educational process is a key component towards International<sup>®</sup> technician certification. You are now required to take a post-test via ISIS<sup>®</sup>/Education/Service/Online testing.

**NOTES**


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